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Chapter 3 – Soil and Water Relations

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Soil/Water

- **Soil physical properties**
- **Soil chemistry**
- **Soil biological properties**
- **Soil moisture**
- **Urban soils**
- **Water relations**
- **Water management**

Physical properties of soil include the texture and structure of soil and their effect on trees.
Soil chemistry includes pH, Cation Exchange Capacity (CEC), buffering effects, and their effects on the availability of essential elements to trees.
Biological - importance of organisms, rhizosphere and mycorrhizae to trees
relationship between **soil moisture**, absorption of essential elements, and root growth
Urban soils – special considerations
gravitational water, field capacity, permanent wilting point, infiltration rate
irrigation methods
evapotranspiration, water holding capacity of soils
how to decrease water loss from roots and trees – mulch, hydrogels, antitranspirants

Knowing how these factors affect trees will help arborist better manage urban trees

Physical Properties

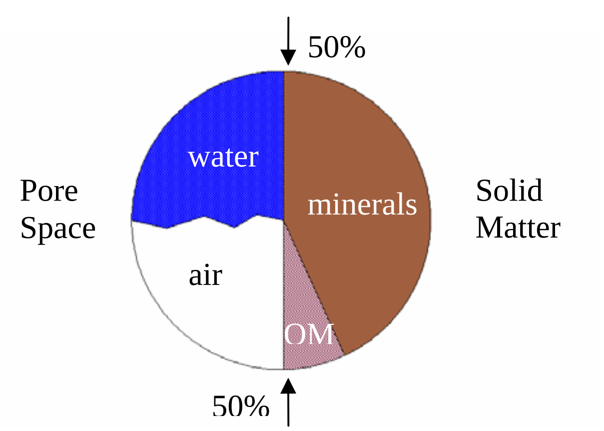
- Parent material
- Volume
- Horizons
- Texture
- Structure
- Compaction

Physical properties of soil include:

How soil is formed from the parent material;
Ideal volume (make-up) of soil;
Soil profile of horizons (layers);
Soil texture and structure;
Effects of compaction on soil.

Soil provides plants with:

- nutrients;
- root anchorage;
- water.



Soil is formed by the weathering and erosion of parent material.

Ideal soil is 50% pore space and 50% solid matter (5% Organic Material (OM) and organisms and 45% mineral).

Pore space is ideally half air, half water. Too much water and the tree drowns; too much air the roots will dry out.

Which of the 4 soil components can be managed? We can manage all these components to some degree.

If the components are out of proportion – it can lead to problems.

Soil Profile

Over time, soil is formed into different layers called "horizons." –

O = Organic layer, decaying plant material, called "humus.";

A = topsoil, most productive layer of soil, commonly referred to as "topsoil." Most of a tree's absorbing roots are found in this horizon;

B = combination of A & C materials

C = subsoil, composed of disintegrated parent material and other minerals**.**

Over time, soil is formed into different layers called "horizons." The layers vary in size and composition for each soil. In some soils all layers may not be present.

Soil is constantly forming through biological (rodents, mycorrhiza, worms, etc.), chemical and physical/environmental (sun, wind, rain, ice) weathering.

Usually soil has four layers –
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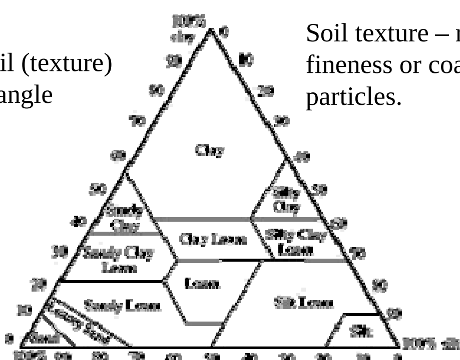
Soil Profile

Most of the trees roots are in the top 12-18" of soil. The absorbing roots in the top 6-10".

The fertility, water holding capability, air spaces to this depth are very important to tree growth and health.

Many urban soils are low in organic material as the nutrient cycle is often interrupted. Plant debris is generally removed from surface in urban areas.

Soil (texture) triangle



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Soil texture – relative fineness or coarseness of particles.

Soil texture is the relative fineness or coarseness of particles.

Soil particles ranked from largest in size to smallest:
- clay – below 0.002 mm
- silt –0.002 mm to 0.05 mm
- sand – 0.05 mm to 2.0 mm

Textural classes are determined by the relative percentages as shown in the soil triangle.

Texture affects soil's ability to hold water and provide oxygen to roots; also affects fertility.

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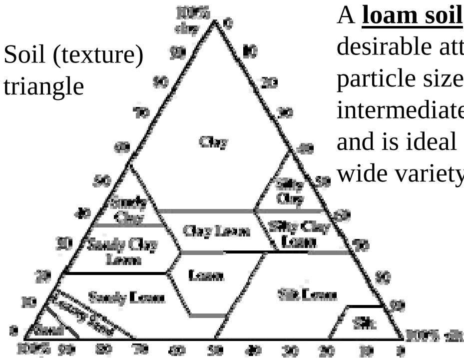
Soil (texture) triangle



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A **loam soil** combines the desirable attributes of each particle size, exhibits intermediate characteristics, and is ideal for growing a wide variety of plants.

A loam soil combines the desirable attributes of each particle size, exhibits intermediate characteristics, and is ideal for growing a wide variety of plants.

Loam is a mixture. It combines desirable attributes of each particle size, exhibits intermediate characteristics, ideal for growing a wide variety of plants.

Loam contains twice as much sand and silt as clay.

Amending a clay soil until it is 50% clay and 50% sand will reduce aeration potential.

In most cases, amending soil backfill with OM will not be any benefit.

No slide

As soil weathers, it forms clumps or aggregates – soil structure. This structure contains spaces between the aggregates that affect aeration and water movement – pore spaces.

Pore space is the area between soil particles. They can be large (macropores) and small (micropores). Macropores tend to be filled with air whereas micropores tend to be filled with water.

Macropores dominate coarse soils, fine soils have more pore space, lower Bulk Density.

Structure can be affected by compaction – reduced pore space, restricted root growth, water infiltration and availability, oxygen and carbon dioxide exchange.

No slide

Why is it important to have air in the soil?
Roots respire just like the leaves. Roots require oxygen and give off carbon dioxide.

Oxygen levels are usually higher near the soil surface so when compaction or flooding occur, the oxygen is limited and the roots are stressed.

Pore spaces contain water and gases. Roots give off CO2 – respiration and gas exchange takes place higher near the soil surface. Compaction and flooding can lead to reduced root function.

Physical Properties

- **Bulk density** = weight of a given volume of soil.
  Useful in appraising soil compaction.
  High BD indicates low porosity.
  Root growth is possible, but restricted, when BD reaches 1.4-1.6 grams per cubic cm
- **Compaction** = soil pores pressed together, pore spaces reduced. Means less water, O2, and CO2 movement.

What are some ways soils can be compacted?
Walking, vehicles, storage, over-watering, incorrect planting.

What are some ways soils can be loosened/aerated?
Discing, vertical mulching, adding soil amendments

Engineering
Preparing soils for structures, roads, and pavement, specifications usually require that the load-bearing soil be compacted to 90-97%. At this compaction level, soil is almost impenetrable to roots.

Lack of O2 is the most common cause for restricted root growth and death; same as flooding or compaction.

Best way to address soil compaction is to prevent it.

Chemical Properties

- **pH** = the degree of acidity or alkalinity of a soil. Affects:
  - availability of some nutrients in the soil;
  - activity of microorganisms.
- **Buffering capacity** = The resistance of water or soil to changes in pH.
- **Cation exchange capacity (CEC)** = the capacity of soil to absorb positively charged ions.

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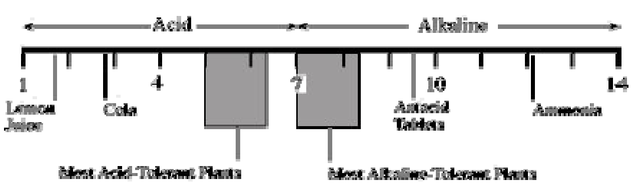
pH = the degree of acidity or alkalinity of a soil. A pH of 7 is neutral soil. From 0 to 7 indicates acidic; 7 to 14 indicates alkaline.

Chemical properties of soils



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The pH scale ranges from 1 to 14. A pH of 7 is neutral, a pH above 7 is alkaline or basic, and a pH below 7 is acidic (figure 5). A pH range of 5.5 to 6.5 is often given as the most favorable for tree growth.

Chemical properties of soils

Soils with a high CEC are negatively charged – soils high in organic matter and clay.

This makes them more fertile because the elements are held by the soil particles and do not leach.

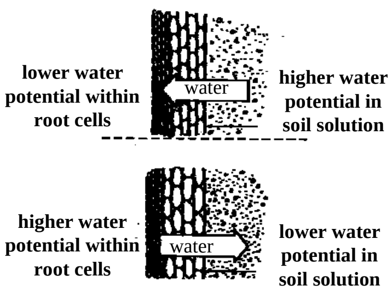
Elements in solution are called ions.
Those that are negatively charged are called anions.
Positively charged are called cations.

The cation exchange capacity (CEC) is a measure of a soil's attraction, retention, and exchange of cations. Capacity of soil to adsorb positively charged ions.

Soils with a high CEC are negatively charged – soils high in organic matter and clay. This makes them more fertile because the elements are held by the soil particles and do not leach.

The salt level in soils may be elevated because of de-icing salts.

A soil that is high in salts has less water available to the roots. Sometimes salts can even draw moisture out of the roots.



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Biological Properties

- **Organisms** = increase aeration, accelerate decay.
- **Rhizosphere** = zone of intense biological activity near actively growing roots.
- **Mycorrhizae** = fungi living in symbiotic relationship with roots, increase ability to absorb water and nutrients.
- **Nutrient cycling** = decomposing leaves, twigs – turn into nutrients, taken up again by roots.

There are billions of **organisms** in soil – mostly beneficial. Worms and insects, for example, help increase aeration and accelerate organic decay.

Some are harmful (nematodes), as they can feed on and damage roots.

Bacteria and fungi – help with decomposition, some cause diseases.

Rhizosphere – zone of intense biological activity near actively growing roots. Source of organic material for organisms.

Mycorrhizae – "fungus roots". Fungi live in a symbiotic relationship with roots, increase the roots ability to absorb water and essential elements.

Nutrient cycling – decomposing leaves, twigs, and wood turn into nutrients which are then taken up again by roots

Biological Properties

Many urban soils are low in organic material because plant debris is usually removed from the soil surface.

Most urban areas remove the fallen organic debris so that the nutrient cycle is disrupted. Organic mulch can sometimes be helpful in these areas.

Soil Moisture

- **Water availability**
- **Gravitational water**
- **Field capacity**
- **Permanent wilting point**
- **Infiltration rate**

Trees need water - nearly all water and elements taken up by the tree are absorbed through root hairs.

Gravitational water is that which drains away from the macropores under the force of gravity (example – sandy soils).

Saturation = water fills both the macropores and micropores.

Excess water drains – gravitational water.
Which component is missing?
Tree root systems need oxygen. This is way flooding and compaction stress and can kill trees.

Saturated soil – all pores in soil are filled with water

Trees require moisture, but it is possible to over water them.

Field capacity = water is held by soil particles after surplus has drained by gravity. Oxygen is available in macropores.

Field capacity is the point at which water is available to plants. The gravitational water has drained away. Water is held by soil particles and can be absorbed by roots or evaporates.

Oxygen is available in macropores.

This is a good conditions for roots.

Permanent wilting point = water is held tightly by soil particles and is unavailable to plants.

At the **permanent wilting point** plants cannot pull water free from the adhesion that holds the water to the soil particles.

No slide

Amount of water soil holds is determined by amount and size of pores and surface area of particles.

Clay holds more water than sand. Clay has more total pore space and surface area and higher water-holding capacity than sandy soil.

Coarse-textured soil has more water readily available than do fine-textured soils.

Tensiometers are soil moisture sensors, used to measure wetness or dryness.

Soil texture affects **infiltration rate** – rate at which water moves through soil profile.

Depth and width of soil moisture movement.

Sandy loam – more macropores

Clay loam – more surface area and adhesion

Amending a clay soil until it is 50% clay and 50% sand will reduce aeration potential.

Aeration improves as a higher proportion of sand is present.

Why will the clay soil saturate before water moves into the sandy soil?

Fine soil over coarse soil – water will not drain down till the upper layer of finer particles is completely saturated.

Coarse soil over clay – water accumulates in upper layer as it slowly infiltrates into lower layer.

If a tree is planted in clay and backfilled with coarse soil, the hole will act as a bowl retaining water; roots could drown

Gravel placed in bottom does not improve drainage.

The most beneficial time to irrigate plants is in the early morning.

Evaporation is minimized and the foliage has time to dry during daylight hours minimizing fungal problems.

Evening watering is also efficient for water use where fungal diseases are not a problem.

Urban soils

- Disturbed
- Lack of Organic Material
- Lack of nutrients
- Altered pH
- Lack of organisms
- Moisture problems
- Compacted

Urban soils are soils usually disturbed by humans. There is no organic horizon. It may:

Be compacted,
contain rubble,
contain few nutrients,
have altered pH,
have few microorganisms,
contain no plant debris,
experience temperature fluctuations

Compaction reduces pore spaces, availability of water, and the lack of oxygen restricts roots. It is best to prevent it.

All can lead to a short life for a tree in urban soil.

Urban soils

When preparing soils for structures, roads, and pavement, engineering specifications usually require that the load-bearing soil be compacted to 90-97%.

This makes the soil almost impenetrable to soils.

Urban soils

The best way address soil compaction is to to proper measures to prevent it from occurring in the first place.

Water Relations

- Water needs
- Transpiration
- Drought
- Water spenders
- Water conservers

Amount of water needed by plants varies with species, plant size, air temperature, humidity, light levels, wind.

A large tree absorbs 100s of gallons water per day, and transpires about 95%.

Transpiration – controlled by stomatal opening and closing, depends on factors above. If transpiration exceeds uptake by roots, plants will wilt. Too much water can also damage trees.

Drought – extended water deficit. Plants wilt, drop leaves, develop modified leaves, increase production of absorbing roots. Prolong drought can lead to death of a tree.

Clays have greater water holding capacity than sands. Sands must be irrigated more frequently, clay has slower infiltration rate – apply water slowly over larger time period.

Tensiometer – soil moisture sensor, used to measure soil wetness or dryness

Some species are **water spenders** that use large amounts of water, have large root systems, and cannot tolerate drought conditions.

Water conservers need less water, can tolerate drought, become dormant during long dry periods or have thick leaves and deep root systems.

No slide

Irrigation

Replaces water transpired by plants or lost through evaporation.

Frequent shallow watering encourages the growth of surface roots, is more subject to drying out, compacts soil surface, and reduces water infiltration.

Infrequent deep watering encourages deeper roots, drought tolerance, natural shrinking and swelling improves soil structure.

Sprinklers apply water uniformly, but can cause compaction; may cause salt buildup if there is no deep watering.

Irrigate entire root area, not just the trunk area, avoid over watering.

Evapotranspiration is the process by which water is discharged to the atmosphere as a result of evaporation from the soil and transpiration by plants.

Factors that affect evapotranspiration include the plant's growth stage or level of maturity, percentage of soil cover, solar radiation, humidity, temperature, and wind.

Water Management

- **Mulches**
- **Hydrogels**
- **Anti-transpirants**
- **Drainage**

Mulches – materials placed on soil surface to reduce moisture evaporation, improve soil conditions, add organic material, reduce weeds, equipment damage, erosion, and help moderate soil temperature.

Hydrogels – hard crystalline polymers – absorb water and expand, slowly release water to soil.

Anti-transpirants – chemicals sprayed on plant to reduce water loss by transpiration – thin coating reduces loss of water through leaf stomates. Can help reduce transplant stress or drought stress.

Drainage – poor drainage can suffocate roots. Drain tiles that slope away from a tree can remove water. Changing the grade, control watering, and select species adapted to wet conditions can help.

Avoid areas where water could collect.

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